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COMPARISON OF LOGGERHEAD SEA TURTLES NESTING TIMES ON NOURISHED AND NATURAL BEACHES

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INTRODUCTION

A sea turtle's ability to successfully or correctly excavate a nest cavity is related to hardness of the beach (Fletemeyer 1980, 1983b; Ehrhart and Raymond 1983; Nelson et al. 1987; Nelson and Dickerson 1988). Nesting sea turtles respond to hard beaches by more frequently rejecting a nest site as evidenced by an increase in false crawls (no nest excavation) and false digs (no eggs laid) or by excavating an atypical nest cavity. These atypical nests are narrower than the normal nest cavity for loggerheads. An additional response may be longer times spent on the beach nesting which may result in physiological stress and increased exposure to disturbances and predation.

This study was conducted to determine if beach hardness affects the time loggerhead sea turtles take to excavate a nest cavity. An additional objective of this study was to determine a range of sand characteristics which may potentially inhibit nesting turtles. This information can be used to establish a level of beach compaction which may require amelioration.

Background On Nesting Sea Turtles

Four species of turtles nest in the United States. The most abundant species, the loggerhead turtle (Caretta caretta) is listed on the Federal Endangered Species List as threatened. The green (Chelonia mydas) and leatherback (Dermochelys coriacea) turtles are much less abundant and federally listed as endangered. A rare nester in the United States, the hawksbill turtle (Eretmochelys imbricata), is also federally listed as endangered.

In the United States, sea turtle nesting begins in early spring, increases to a peak in late spring to mid-summer, and declines until completion in late summer (August-September) (Fletemeyer 1981, 1982, 1983a, 1983b; Stoneburner 1981; Richardson and Richardson 1982). Female sea turtles generally nest at intervals of 1 to 3 years, although a small percentage nest at intervals of more than 3 years (Richardson and Richardson 1982; Bjorndal, et al. 1983; Ehrhart and Raymond 1983). When a sea turtle nests, she will usually lay two or three clutches (range, one to five) of eggs per season (Ehrhart 1979; Talbert et al. 1980; Fletemeyer 1981; Richardson and Richardson 1982). Sea turtles are often very site specific when returning to a nesting beach during and between nesting seasons. Loggerheads are considered to be less site specific than green turtles (Caldwell, et al. 1959; Talbert et al. 1980; Bjorndal et al. 1983). Sea turtles may return to a beach to nest because of imprinting to that particular beach (nest site fixity) (Carr 1967) or by following other nesting females to the nesting beach (social facilitation) (Hendrickson 1958).

Sea turtles emerge from the ocean surf at night and crawl ashore. Approximately 30 to 40 percent of the time when sea turtles crawl onto the beach, they return to the water without depositing eggs (false crawls) (Stoneburner 1981; Ehrhart and Raymond 1983; William-Walls et al. 1983). The process of a turtle excavating a cavity without laying eggs is referred to as a false dig. The reason for these false crawls and false digs is not well understood, but probably are influenced by a turtle's "readiness" to lay, physical properties of the beach, temperature of the beach sand, and disturbance to the emerging turtles (Mann 1978, Fletemeyer 1981; Stoneburner and Richardson 1981; Ehrhart and Raymond 1983; Raymond 1984, Nelson et al. 1987). Beaches with too firm a consistency may inhibit or prevent turtles from digging nests (Ehrhart and Raymond 1983; Williams-Walls et al. 1983; Nelson et al. 1987). Turtles emerging from the ocean may return to the water without nesting if they encounter human or animal activity or lights shining directly onto the beach (Mann 1978; Fletemeyer 1979; Ehrhart and Raymond 1983).

Sea turtles usually deposit their nests of 35 to 250 eggs between the mean high tide and the top of the primary dune (Hopkins and Richardson 1984; Nelson 1986). Loggerhead nests are generally located throughout this area while green and leatherback nests tend to be closer to the dunes. Each female turtle may make zero to four false digs before finally laying eggs in a cavity (Ehrhart and Raymond 1983; Nelson et al. 1987). The nesting process (emergence onto the beach, digging of a nest cavity, egg-laying, egg-covering and return to the water) usually takes approximately one hour for loggerheads and even longer for greens and leatherbacks (personal observation). The "light bulb" shaped nests are usually dug to an average depth of about 20 inches (50 cm) for loggerheads and 36 inches (76 cm) for greens and leatherbacks (measured from the beach surface to the bottom of the cavity). Sea turtle eggs hatch in 45 to 75 days (Nelson 1986).

Potential Physical Change Resulting From Beach Nourishment

Sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content potentially can be changed by beach nourishment.

Harder or more compact nourished beaches result primarily from increased beach density and layering of flat sand grains. Harder beaches can be measured for differences in shear resistance with a cone penetrometer. Shear resistance is a measure of the ability to penetrate the sand. Compaction is the reduction in the volume of the sand to a greater density. Shearing resistance is usually higher in a more compact, or denser beach; however, beaches with the same density may have different shear resistances. Shear resistance is affected by grain size distribution, grain shape and orientation, and weight of the overburden (Means and Parcher 1963; Griffiths 1967). Sand of more uniform size (poorly graded) tend to be less densely packed and thus less resistant to shearing (penetration) than well-graded (different-size) sand. Sand grains with an angular shape resist penetration (higher shear resistance) more than smooth-edged grains. Flat-shaped (nonspherical) sand grains will exhibit better resistance to penetration when oriented parallel to the beach surface than when oriented at angles to the beach surface. Shear resistance is increased by the pressure of overburden material (amount/weight); thus, shear resistance will increase with depth in the beach. Grain size gradation, grain shape, and grain orientation interact with each other to affect the density and thus the weight of the overburden. During the nourishment process, beach density/shear resistance may be increased by the operation of construction equipment on the beach and the weight of the hydraulically pumped material (Nelson et al. 1987).

Harder, compacted beaches are not a result of all nourishment projects (Nelson et al. 1987; Wolf et al. 1986). Sand dredged from high energy locations (e.g. inlets) tend to be coarser with smooth eroded surfaces. These smoother, coarser grains tend to form less compacted beaches than the more angular, finer grains from stable offshore borrow sites (Nelson and Mayes 1986; Wolf et al. 1986). A survey of shear resistances of 15 natural beaches and 10 nourished beaches along the east coast of Florida indicates a wide range of shear resistances (Nelson and Dickerson in preparation) (Figures 1 and 2). Only four of the 10 nourished beaches were extremely compact. These four beaches (Jupiter Island, Pompano, John U. Lloyd, and Haulover) had shear resistances in excess of 750 cone index values. Based on observations of these hard beaches, the compacted characteristic can last from 1 to 7 or more years after nourishment depending on the rate the beach is eroded and reformed by weather and waves.

METHODS

Times

Nesting turtles were observed and timed at night during the summers of 1986 and 1987 at Delray Beach and Jupiter Island Beach, Florida. Night vision equipment were used to improve observation and to prevent disturbance of nesting turtles.

The total nesting time was divided into five time periods to aid in measurement and interpretation: approach, dig, lay, cover,

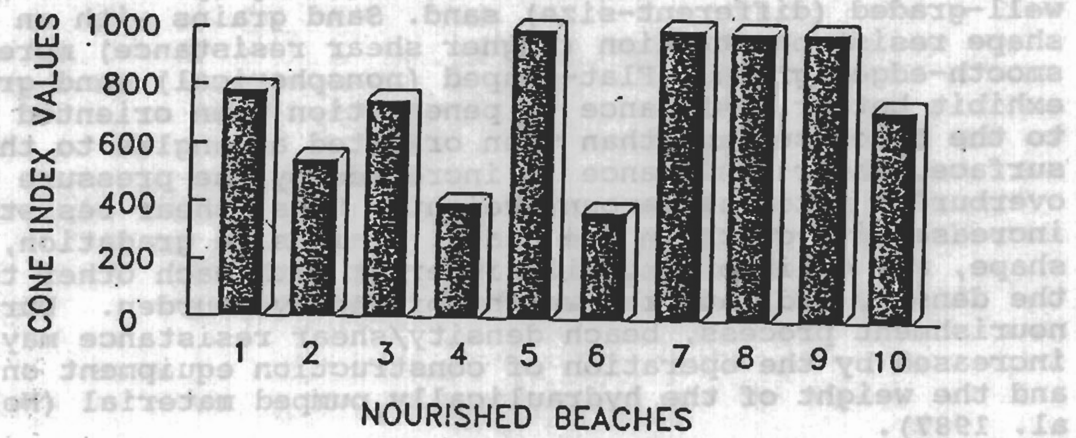


Figure 1. Sheer resistance measurements in cone index values at the depth interval 12 inches below the beach sand surface for the following 10 Florida east coast beaches: 1) Fernandina, 2) Jetty Park, 3) Hutchinson Island, 4) St. Lucie Inlet, 5) Jupiter Island, 6) Boca Raton, 7) Pompano, 8) John U. Lloyd, 9) Haulover, 10) Key Biscayne.

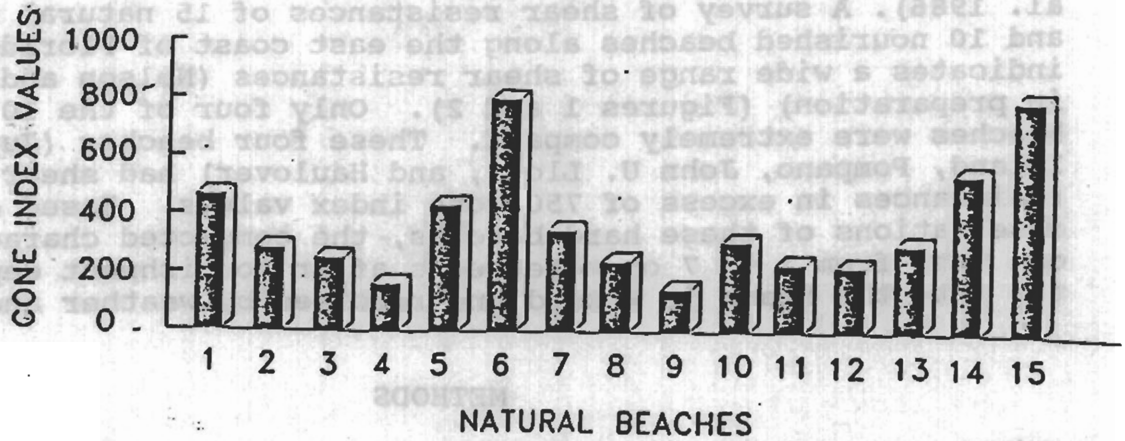


Figure 2. Shear resistance measurements in cone index values at the depth interval 12 inches below the beach sand surface for the following 15 Florida east coast beaches: 1) Little Talbot Island, 2) Canaveral National Seashore, 3) Melbourne Beach, 4) Sebastian Inlet, 5) Vero Beach, 6) Hutchinson Island, 7) Ft. Pierce, 8) St. Lucie Inlet, 9) John D. MacAuthor SRA, 10) Hobe Sound NWR, 11) Jupiter Island, 12) Highland Beach, 13) Boca Raton, 14) Port Everglades, 15) Golden Beach.

and retreat stages. The approach stage was from the emergence from the water to the initiation of digging. The dig stage was from the initiation of digging to the initiation of egg laying. The lay stage was from the initiation of egg laying to the completion of egg laying. The cover stage was from the completion of egg laying to the completion of covering of the nest. The retreat stage was the time from completion of covering of the nest to the entering of the ocean. Stages were timed with a stop watch and recorded to the nearest second.

Hardness/Shear Resistance

Three shear resistance measurements were taken at each nest site. Measurements were taken using a cone penetrometer. The penetrometer has a shaft that is 18 inches long ((45.6 cm) and 3/8 inch diameter (0.95 cm). A cone attached to the bottom of the shaft was 0.2 sq in (1.25 sq cm) in maximum diameter and tapered at 30 degrees to its tip. A proving ring and a 0-750 dial (marked in cone index units) was attached to the upper end of the shaft. Cone index values were recorded at sand depths of 6, 12, and 18 inches (15.2 cm, 30.4 cm, and 45.6 cm, respectively) (Tables 1,2,3). The penetrometer tip was manually pushed into the sand and the cone index values were recorded at each 6 inch depth intervals. We felt measurements taken after digging away each 6 in. depth were more representative of how a turtle might encounter the sand than measurements taken during a single long penetration. If a large rock, shell, or void was encountered, the measurement was retaken. If the substrate was impenetrable with the penetrometer, a cone index value of 999 was recorded.

Analysis

SPSS-PC statistical analysis package was used to analyze data. Cone index values were analyzed with Oneway Analysis of Variance to test equality of mean penetration measurements and mean times for nesting turtles. Pearson's correlations were used to compare times with cone index values.

T-tests were used to compare times between hard versus soft nest sites. When the observed significance level for the F-test was small, (< 0.05) the hypothesis that the population variances are equal is rejected, and the separate-variance t test for means was used. When the significance level for the F-test was large, the pooled-variance t-test was used (Norusis 1988).

The times for each nesting stage (approach, dig, lay, cover, and retreat) were compared by cone index values at the 12 inch depth interval. Previous studies have demonstrated that the 12 inch depth interval to be the most indicative of beach hardness (Nelson et al. 1987). Measurements at this depth are less disturbed by beach activity than the 6 inch depth interval and do not exceed the measurement ability of the penetrometer.

Table 1. Comparison of times for nesting stages between hard (compacted) and soft (uncompacted) nest sites (t-test)

Nesting Stage	Hard ness	Mean (min)	SD	SE	n	t	prob.
Total[1]	soft[2]	75.98	16.32	2.88	32	-2.98	0.006
	hard	113.00	32.57	23.03	2		
Subtotal[3]	soft	66.41	14.29	2.21	42	-2.64	0.115[4]
	hard	114.82	31.55	18.22	3		
Approach	soft	9.59	6.56	1.16	32	-1.03	0.312
	hard	14.79	14.19	10.04	2		
Dig	soft	19.92	5.39	0.81	44	-1.56	0.259[4]
	hard	51.67	35.25	20.35	3		
Lay	soft	14.40	3.77	0.50	56	0.57	0.571
	hard	13.29	3.57	1.78	4		
Cover	soft	25.57	7.99	0.97	68	-2.35	0.022
	hard	34.16	6.26	2.80	5		
Retreat	soft	5.62	4.11	0.49	71	-0.79	0.474
	hard	9.61	11.27	5.04	5		
pen6	soft	125.10	62.41	7.46	70	-2.64	0.057[4]
	hard	489.60	307.83	137.67	5		
pen12	soft	254.54	135.89	16.24	70	-10.86	0.000
	hard	937.80	137.85	61.20	5		
pen18	soft	354.25	231.40	27.66	70	-18.79	0.000[4]
	hard	980.40	41.59	18.60	5		

[1]Total = all stages: approach, dig, lay, cover, and retreat
[2]Soft = $\leq$600 cone index; hard = >692 cone index, at 12 in depth (note: no available observations for 601-692 or 694-998)
[3]Subtotal = dig, lay, cover, and retreat stages only
[4]Separate variance estimate used for t-test

Table 2. Correlation of cone index values with nesting times. for nest sites with a cone index ≤600 (soft nest sites)

Nesting Stage	n	coefficient probability 6 inch	12 inch	18 inch
Total	32	-0.2917	-0.0014	0.0114
Subtotal	42	-0.2685	-0.0548	-0.0216
Approach	32	-0.0122	0.1552	0.1980
Dig	42	0.0144	0.1822	0.2856
Lay	56	-0.2776	-0.1741	-0.2333
Cover	65	-0.1942	-0.1905	-0.0158
Retreat	68	-0.0774	-0.0551	-0.0248

no values were significant

Table 3. Times for each nesting stage and cone index values for soft and hard nest sites.

NESTING STAGE	CONE INDEX RANGE <100	101-200	201-300	301-400	401-500	501-600	690-900	Total
APPROACH								
Mean	10.43	9.86	8.06	7.27	12.07	18.00	14.79	9.90
SD	-	7.30	7.16	3.62	6.92	-	14.19	6.93
n	1	16	6	5	3	1	2	34
DIG								
Mean	15.35	20.62	17.24	20.61	22.28	25.00	51.67	21.94
SD	4.16	6.28	2.75	4.21	5.97	-	33.25	12.17
n	3	18	9	6	5	1	3	45
LAY								
Mean	16.61	14.76	13.89	14.34	12.91	13.89	13.29	14.32
SD	4.53	3.85	3.23	3.88	4.21	4.40	3.57	3.74
n	5	20	13	9	7	2	4	60
COVER								
Mean	22.98	27.90	24.19	25.34	23.08	20.67	34.16	26.00
SD	7.32	9.81	5.03	7.65	6.23	9.06	6.26	8.20
n	5	25	14	9	9	3	5	70
RETREAT								
Mean	8.15	4.84	5.34	5.68	5.27	4.75	9.61	5.66
SD	7.74	2.52	3.11	4.80	2.28	2.85	11.27	4.48
n	5	26	16	10	8	3	5	73
TOTAL								
Mean	77.72	79.00	69.11	69.66	79.26	89.00	113.00	78.16
SD	-	18.75	12.52	4.49	25.27	-	32.57	18.98
n	1	16	6	5	3	1	2	34
SUBTOTAL								
Mean	58.91	70.25	60.84	68.49	63.67	71.00	114.82	69.93
SD	14.41	16.20	7.27	15.87	15.96	-	31.55	19.61
n	3	18	9	6	5	1	3	45

RESULTS AND DISCUSSION

Nesting Times for Hard versus Soft Nest Sites

The nesting beaches were either soft (unnourished) (200-600 cone index values, 12 inch depth) or very hard (nourished) (>999 cone index values) (except for one site which had a mean value of 693 cone index values). The mean times for the approach, lay, and retreat nesting stages were not significantly different between soft nest sites (cone index values $\leq$ 600) and hard nest sites (cone index values >690) (Table 1, Figure 3). The mean times for the cover nesting stages were significantly higher ($p = 0.022$) for hard nest sites than for soft nest sites. The mean times for the dig nesting stages were higher for the hard nest sites but not signifcantly ($p = 259$). Because of the large variation in the times a larger sample size is needed to detect differences in dig times. The total time which included the sum of the approach, dig, lay, cover, and retreat stages was significantly higher for hard nest sites (Figure 4). However, this should not be considered definitive since the sample size for the hard beach sites was very small ($n = 2$). The subtotal time which included only the sum of dig, lay, cover, and retreat stages was not significantly different between the soft and hard nest sites.

The approach or retreat times would not be different for the two nest site types unless a turtle crawls a greater distance or moves slower to find a suitable nest site on a hard beach or a soft beach. A previous study by Nelson et al. (1987) provides evidence that nest site locations were not significantly different in distance from the wrack lines for hard nourished beaches versus soft natural reference beaches. The rejection of a nest site may be more frequent on a hard beach, as evidenced by a higher ratio of false crawls to nests (Ehrhart and Raymond 1983 , Nelson et al. 1987, Nelson and Dickerson 1988). However, the selection of a nest site does not appear to be affected by hardness of a nest site, as evidenced by mean distances from the wrack line of nest sites and mean times spent establishing and retreating from a nest site.

Sea turtles are very large and powerful animals and have the ability to dig nest cavities in a wide range of beach consistencies. However, a beach hardness level may be reached that inhibits a turtles ability to dig. Nest sites with higher cone index values and longer dig times are outside the "tolerance" range for the turtles digging abilities. Two nest sites with high cone index values (> 999 cone index values) did have longer digging times (36.3 min and 92.0 min) (Figure 5). However, not enough times were observed with high cone index values to provide statistically meaningful results for dig times on hard nest sites. The dig times for soft nest sites did not increase with cone index values (Table 2). This suggests that these values are within the "tolerance" range of loggerhead turtles.

The degree of hardness which begins to effect dig times is

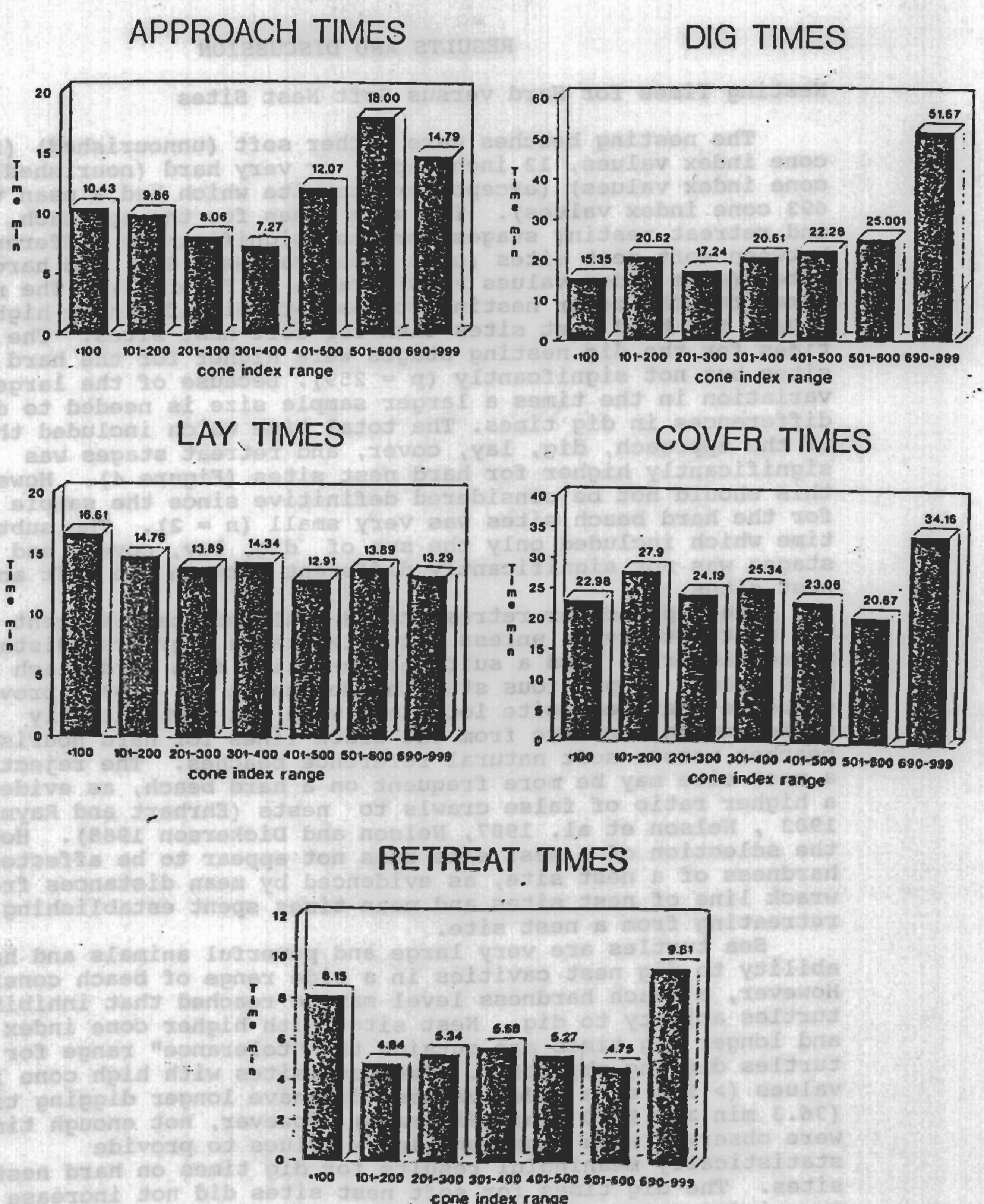
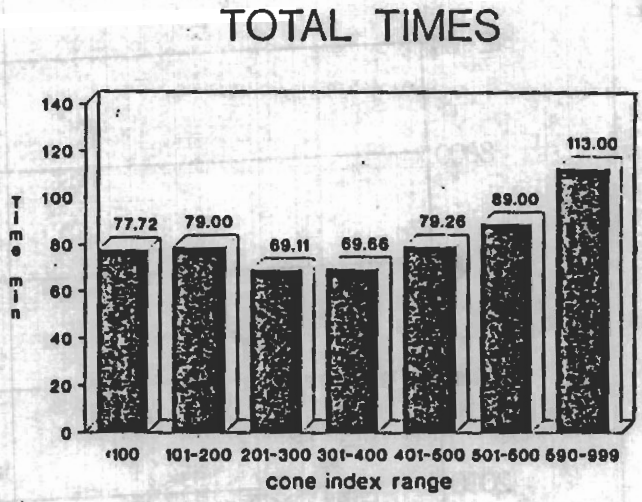


Figure 3. Nesting stage times for each stage by cone index value ranges.



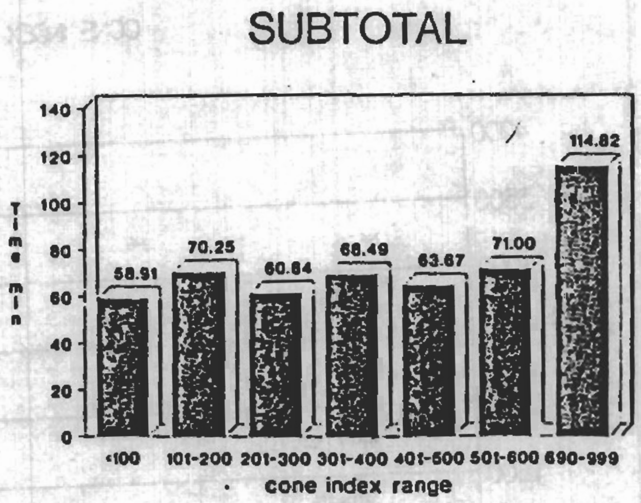


Figure 4. Cummulative nesting stage times by cone index value ranges. Total times = all nesting stages, Subtotal times = all nesting stages except approach stage.

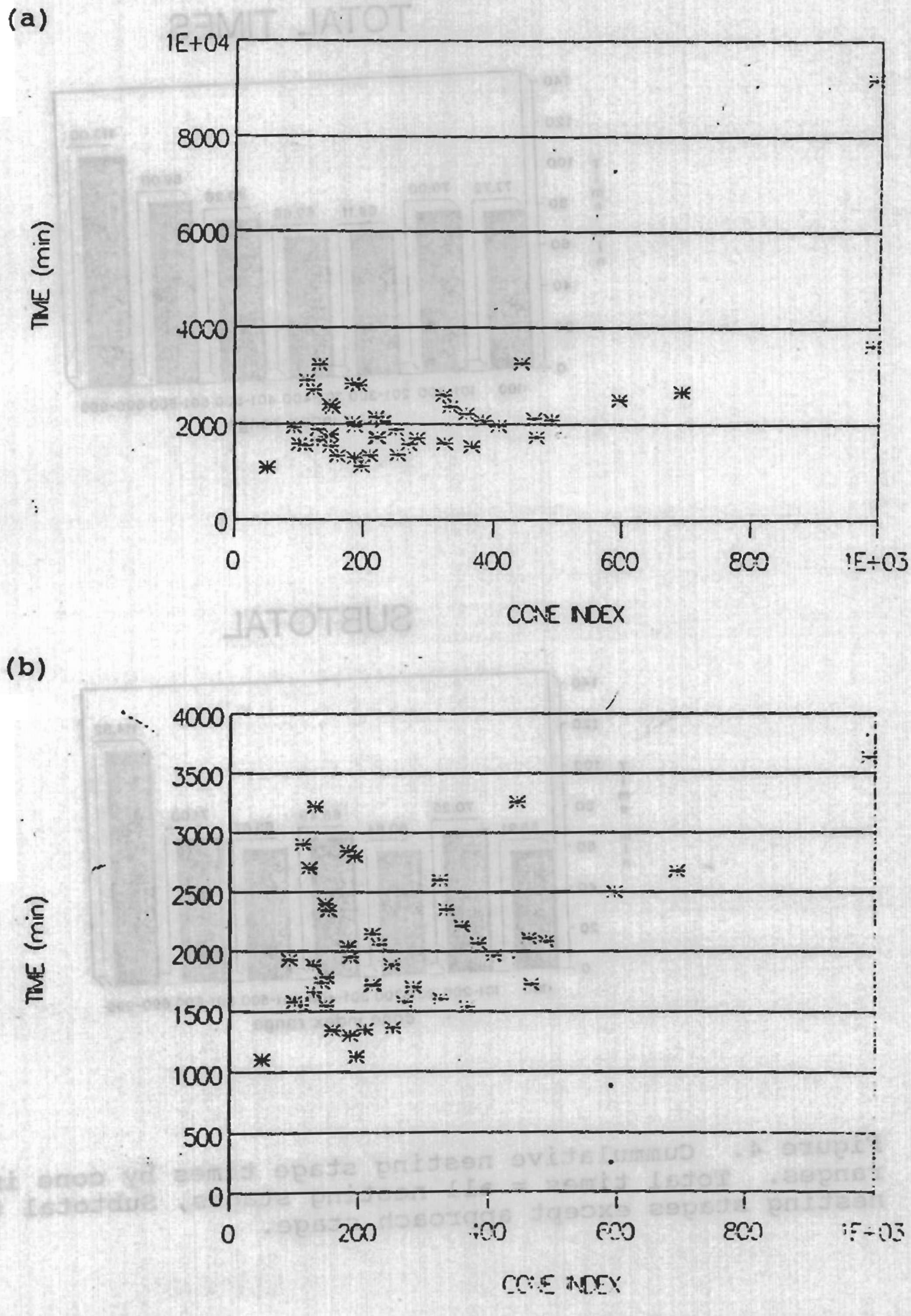


Figure 5. Dig times versus cone index values at 12 in. depth. (a) all sites, n = 45, (b) less outlier, n = 44

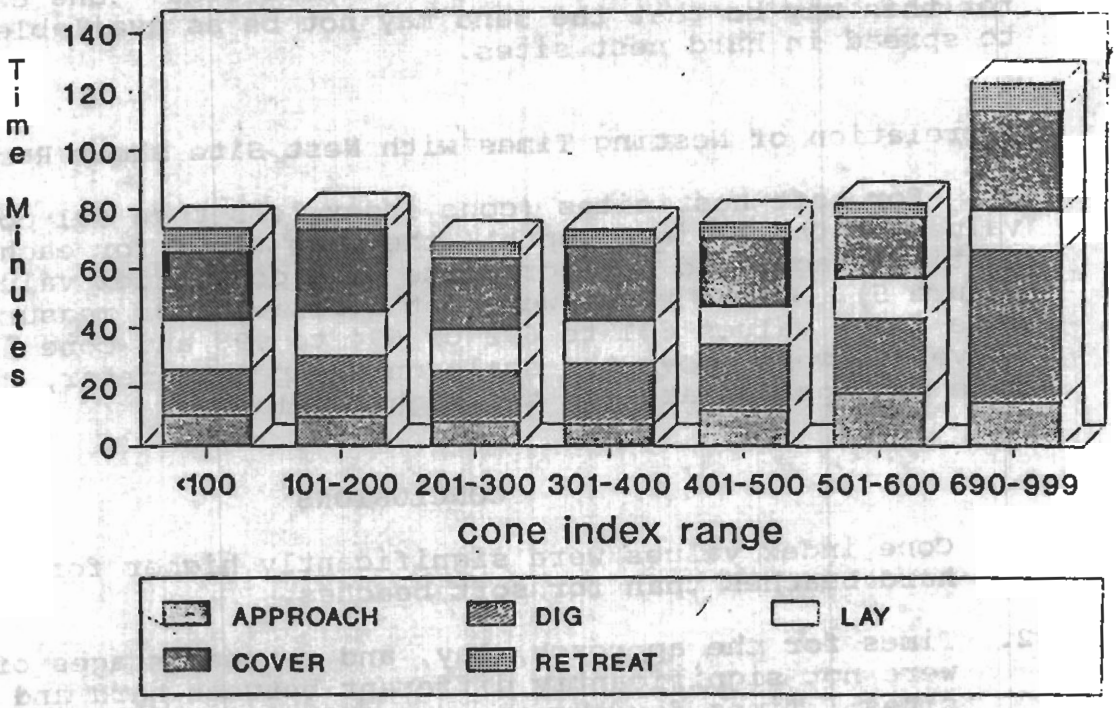


Figure 6. Cummulative nesting stage times for each cone index value range.

above 600 cone index values (Figure 3 and 6). However, data on nest sites with cone index values between 600 to 692 or 694 to 998 were not obtained in this study. Nesting beaches with intermediate cone index values were not observed in this study. Obtaining data on nest sites with a specified degree of hardness is difficult because the time and location where turtles nest is not predictable. Observations of turtles must be made as they are encountered.

Covering times were longer in hard sand. One explanation for this may be that the sand may not be as available or as easy to spread in hard nest sites.

Correlation of Nesting Times with Nest Site Shear Resistance

For soft nest sites (cone index less than 601 cone index values at the 12 inch depth), the mean times for each of the five nesting stages did not correlate with cone index values (Table 2, Figure 5). Since times were not available for measurements with cone index values 601 to 692 or 694 to 998 and cone index values above 800 were above the scale on the penetrometer, correlations were not appropriate for the higher values.

CONCLUSIONS

1. Cone index values were significantly higher for nest sites on hard beaches than for soft beaches.

2. Times for the approach, lay, and retreat stages of nesting were not significantly different between hard and soft nest sites. Times for the cover stage of nesting was significantly higher for hard nest sites than for soft nest sites ($p = 0.022$). Although not significantly different ($p = 0.259$), times for the dig stage were higher for hard nest sites than for soft nest sites. Since only two dig times were observed for very hard sites (> 999 cone index values) additional observations are needed to establish a maximum tolerance value for hard nest sites.

3. The total times for the sum of all stages of nesting were significantly higher for hard nest sites than for soft nest sites. However, this should not be considered definitive since the sample size for the hard beach sites was very small. The times for the subtotal of dig, cover, lay, and retreat (approach time excluded) were not significantly different for the two levels of hardness.

4. The times for each nesting stage did not correlate with cone index values for nests sites less than 600 cone index values. Nest sites with cone index values below 600 did not affect nesting excavation times.

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REFERENCES

Bjorndal, K. A., Meylan, A. B., and Turner, F. J. (1983). "Sea Turtles Nesting at Melbourne Beach, Florida; I: Size, Growth, and Reproductive Biology." Biological Conservation, 26, 65-77.

Caldwell, D. K., Carr, A., and Ogren, L. H. (1959). "The Loggerhead Turtles of Cape Romain, South Carolina." Bulletin of the Florida State Museum, 4(4),320-348.

Carr, A. (1967). So Excellent a Fishe, Natural History Press, NY, 1-288.

Ehrhart, L. M. (1979). "Patterns of Sea Turtle Mortality on the East-Central Florida Coast, 1977-78." Florida Science, 41, 26.

Ehrhart, L. M. and Raymond, P.W. (1983). "The Effects of Beach Restoration on Marine Turtles Nesting in South Brevard County, Florida." US Army Corps of Engineers, Jacksonville, Florida, 1-47.

Fletemeyer, J. (1979). "Sea Turtle Monitoring Project." Report to Broward County Environmental Quality Control Board, Broward County, FL.

Fletemeyer, J. (1980). "Sea Turtle Monitoring Project." Report to Broward County Environmental Quality Control Board, Broward County, FL.

Fletemeyer, J. (1981). "Sea Turtle Monitoring Project." Report to Broward County Environmental Quality Control Board, Broward County, FL.

Fletemeyer, J. (1982). "Sea Turtle Monitoring Project." Report to Broward County Environmental Quality Control Board, Broward County, FL.

Fletemeyer, J. (1983a). "Sea Turtle Monitoring Project." Report to Broward County Environmental Quality Control Board, Broward County, FL.

Fletemeyer, J. (1983b). "The Impact of Beach Renourishment on Sea Turtle Nesting (Abstract)." presented at 1983 meeting of the American Shore and Beach Preservation Association and The Florida Shore and Beach Preservation Association, Boca Raton, FL.

Griffiths, J.C. (1967). Scientific Methods and Analysis of Sediments., McGraw-Hill Book Company, New York.

Hendrickson, J. R. (1958). "The Green Turtle, Chelonia mydas (Linn.), in Malaya and Sarnivak." Proceedings of the Zoological Society of London, 130, 455-535.

Hopkins, S. R. and Richardson, J. I. (1984). "Recovery Plan for Marine Turtles." US Department of Commerce, National Oceanic and Atmospheric Association, National Marine Fisheries Service, St. Petersburg, FL.

Mann, T. M. (1978). "Impacts of Developed Coastline on Nesting and Hatchling Sea Turtles in Southeastern Florida." Florida Marine Research Publication, 33, 53-55.

Means, R. E. and Parcher, J. V. (1963). Physical Properties of Soils. Charles E. Merrill Books, Inc., Columbus, Ohio.

Nelson, D. A. (1986). " Pilot Study on the Use of Tilling to Soften Sand Consistency After Beach Nourishment." Draft Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Nelson, D. A. and Mayes, C. H. (1986). "St. Lucie Inlet Dredged Material Disposal Effects on the Firmness of Sand Used by Nesting Turtles." US Army Engineer Waterways Experiment Station, Vicksburg, MS, 1-24.

Nelson, D. A. and Dickerson, D. D. (1988). "Response of Nesting Sea Turtles to Tilling of Compacted Beaches, Jupiter Island, Florida," US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Contract Report to US Army Engineer District, Jacksonville.

Nelson, D. A., Mauck, K. A., and Fletemeyer, J. (1987). "Physical Effects of Beach Nourishment on Sea Turtle Nesting, Delray Beach, Florida." U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, TR-87-15, 1-56.

Norussis, M. J. 1988. SPSS/PC+V2.0 Base Manual for the IBM PC/XT/AT and PS/2. SPSS Inc. Chicago, IL 600 pp.

Raymond, P. W. (1984). "The Effects of Beach Restoration on Marine Turtles Nesting in South Brevard County, Florida." Master's Thesis, University of Central Florida, Orlando, FL, 1-121.

Richardson, J. I. and Richardson, T. H. (1982). "An Experimental Population Model for the Loggerhead Sea Turtle (Caretta caretta)." Biology and Conservation of Sea Turtles, K. A. Bjorndal, ed., Smithsonian Institution, Washington, DC.

Stoneburner, D. L. (1981). "Summary of the Loggerhead Sea Turtle Research Project Coordinated at Canaveral National Seashore, Cumberland Island National Seashore, Cape Lookout National Seashore: A Final Report." Research/Resources Management Report, US Department of the Interior, National Park Service, Atlanta, GA, vol 39.

Stoneburner, D. L. and Richardson, J. I. (1981). "Observation on the Role of Temperature in Loggerhead Turtle Nest Site Selection." Copeia, 1, 233-241.

Talbert, O. R., Jr., Stancyk, S. E., Dean, J. M., and Will, J. M. (1980). "Nesting Activity of the Loggerhead Turtle (Caretta caretta) in South Carolina; I: A Rookery in Transition." Copeia, 4, 709-718.

William-Walls, N., O'Hara, J., Gallagher, R. M., Worth, D. F., Peary, B. D. and Wilcox, J. R. (1983). "Spatial and Temporal Trends of Sea Turtle Nesting on Hutchinson Island, Florida, 1971-1979." Bulletin of Marine Science, 23(1), 55-66.

Wolf, R. E., Shoup, L. P., and Pyles, W. T. (1986). "1986 Sea Turtle Protection and Nest Monitoring Program Report." City of Boca Raton Monitoring Report, Boca Raton, FL, 1-33.